AFIT/GCM/LAS/99S-2

IMPLEMENTATION OF EARNED VALUE MANAGEMENT INTO THE SOFTWARE ACQUISITION PROCESS

THESIS

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Abstract

The objective of this study was to determine the usefulness of Earned Value Management as a program management tool for the Department of Defense acquisition community. In making this determination, the study sought to uncover information about Earned Value Management from the contractor's perspective as well as the government administrator's perspective. It also sought to determine the usefulness of Earned Value Management during the different phases of the software acquisition process.

The study utilized a questionnaire to acquire the data necessary for analysis. This data was analyzed to compare perceptions of the government and contractor communities in regard to the use of Earned Value Management as a program management tool. It also compared perceptions in regard to using Earned Value Management during different stages of the software program life cycle.

IMPLEMENTATION OF EARNED VALUE MANAGEMENT INTO THE SOFTWARE ACQUISITION PROCESS

I. Introduction

Background

The Department of Defense (DOD) has major difficulties in translating mission needs into efficiently procured and operational systems. One of the aspects of this difficulty is the acquisition of the software systems that comprise the heart and soul of the product. In the absence of an efficient and effective software system, the overall acquisition program will experience skyrocketing cost and schedule variances. GAO reports on nine DOD software contracts cite cost overruns as fairly common in more than 50 percent of the cases and schedule overruns in more than 60 percent (Frank, 1983). Of $6.8 million expended on the contracts, the results included the following:

Software delivered, but never used:	$3.2 million
Software paid for, but never delivered:	$1.9 million
Software extensively reworked before use:	$1.3 million
Software used after changes:	$198,000
Software used as delivered:	$119,000

Effective project management is key to the successful development of software projects in an overall acquisition program. According to the Project Management Institute, project management is:

> The art of directing and coordinating human and material resources throughout the life of a project by using modern management techniques to achieve predetermined objectives of scope, cost, time, quality and participant satisfaction. (Caudle 1999)

Through the use of adequate and appropriate project management tools, acquisition officials can have control of the software development process by guarding against cost, schedule and performance deviations.

In the face of reduced budgets and increased congressional scrutiny, the DOD must find ways to acquire their complex and unique systems more efficiently and effectively. DOD Directives 5000.1 and 5000.2-R set the basis for accomplishing acquisition goals in this new environment. Under the category of organizing for efficiency and effectiveness, DODD 5000.1 recognizes the need for limited reporting requirements, automated acquisition information and management control.

Limited reporting requirements are an attempt to prevent the government from overburdening contractors with requests for engineering information and data presentation,

which the government cannot fully analyze and assess anyway. Reporting requirements should be limited to information necessary to understand program status and make informed decisions.

Automated acquisition information (AAI) involves having an infrastructure to provide current and comprehensive information to decision-makers. It attempts to give program managers access to management information tools that facilitate efficient and effective acquisition. It involves having readily available information to encourage responsiveness to the internal and environmental factors that effect the dynamic and complex software acquisition process.

Management control is absolutely necessary to promote effectiveness and accountability. Achieving efficiency and effectiveness means maximizing the utilization of limited resources through management control. Cost, schedule and performance parameters must be understood, quantified and controlled to ensure successful project acquisition. Deviations from Acquisition Program Baselines (APBs) must be identified and countered at the earliest possible indication to prevent cost, schedule or performance variations threatening program existence.

Problem Statement

Earned Value Management is a project management tool available to the acquisition community for managing these deviation risks. This management tool attempts to facilitate and satisfy the requirements of DODD 5000.1 for achieving limited reporting requirements, automated acquisition information and management control.

Earned value is used to break the software project down into distinct, identifiable units and place a budgeted cost and schedule allotment against each of these units. The system is designed to allow immediate access into the current progress of work completed and the cost and schedule expended in achieving this work. This management program seeks to identify cost, schedule and performance risks as early as possible by identifying when deviations occur from the baseline objectives. This allows management to direct attention to the problem or perform trade-off analysis to keep the project within cost, schedule and performance constraints.

In order for Earned Value Management to be successful, there are several requirements that the management system must satisfy. The potential of Earned Value Management must be appreciated and realized if it is to be successfully

implemented into the program management scheme. The success of Earned Value Management is based on the following: capability over prior systems of management control, contractor and government usability, insight and representation of program metrics, adequacy for use over the life cycle of the project.

The fulfillment of these objectives is necessary to help the federal government bring the acquisition of software products under cost, schedule and performance control. The applicability and feasibility of Earned Value Management needs to be discerned before the DOD spends time and effort instituting this program management scheme, only to find it to be unimproved over current project management methodologies.

Research Objectives

The objective of this study is to determine and compare government and contractor perceptions of the usefulness and applicability of the Earned Value Management philosophy. The ultimate success or failure of the earned value philosophy is dependent on its useful application by the practicing acquisition community – both by government and contractor representatives. These perceptions will

provide information useful in determining the legitimacy and power of the Earned Value Management process.

This objective is sought by determining the level of insight acquisition professionals familiar with earned value have attained and desire. The degree of usability will also be gauged. This should help determine the effectiveness of Earned Value Management in the fulfillment of its role as a productive program management tool.

There are two other purposes of the study. The study seeks to understand the applicability of earned value across the entire software life cycle. It is sought to determine the perceived usefulness of earned value in comparison to previous program management schemes. These objectives will help determine whether earned value is a broad-based application or an augmentation of current program management tools, applicable during only specific portions of the acquisition process.

Research Focus

This study will focus on the perceptions of the usefulness and applicability of the Earned Value Management philosophy. This will be accomplished with analysis of perceptions from both from the contractor and the

government perspective. This will provide insight into the quality and utility of the Earned Value Management process for software project throughout the software life cycle from each sector's point-of-view.

This study also is an analysis of the comparison between the government and contractor perspectives. This will be useful in determining whether philosophy gaps exist and if the government is adopting commercial or directing government-mandated practices.

Furthermore, this study seeks to report the types of metrics used for assessing the value that the contractor has earned within a given reporting period. This information will be important for understanding the standardization and specialization that exist among the broad range of respondents. This information may also indicate variation in the application and utilization of the program management scheme.

Methodology

The design of this study is based on a structured questionnaire of government and contractor acquisition professionals. The questionnaires were distributed throughout the local government and contractor community

for their responses. The structured questionnaire consists of statements in several different categories and their relation to the Earned Value Management process. The categories gauge the responses based on the Likert Scale by choosing one of five agreement choices (Cooper 1979).

The responses will be distinguished between government and contractor subjects. The responses will be analyzed to determine the mean level assessment of Earned Value Management for each of the identified categories. This will determine the overall level of satisfaction from both the government and contractor perspective of the success of the earned value scheme.

The categorized responses will then be analyzed between government and contractor subjects to determine differences in the perceptions of the utility of Earned Value Management. This analysis of means will help determine whether or not the government and contractor realize the same benefit or detriment from the use of the earned value scheme.

Assumptions/Limitations

This study does not distinguish between the size and complexity of software acquisition projects, which may be a

determinant of the project management scheme employed. It also does not distinguish between the type of software project, which may range from space command and control to aircraft navigation to accounting and finance budgeting systems. The cost estimation and work breakdown structure units may be of dissimilar size and scope, which may affect the relative utility of the earned value success in tracking and controlling work progression.

The only distinction for the subjects of this study is whether the participant is identified as a government official or a contractor. This does not take into account differences between senior, mid and lower level managers. There is also not a distinction between whether the government officials are military or government civilians.

Implications

The results of this study could yield important and crucial information for government acquisition executives. This study will determine the perceived usefulness and applicability of Earned Value Management in the current acquisition environment. It will help in determining if philosophical and perceptual differences exist between the

contractor and government communities concerning the utility of the Earned Value Management System.

The results may validate a program manager's decision to employ Earned Value Management or the search for alternative program management schemes. Analysis of the objectives (capability, usability, insight and life cycle adequacy) may suggest that the program manager implement an Earned Value Management System, find an alternative system, or retain the current system.

Preview

The control of cost, schedule and performance are paramount to the success of a software acquisition. Identifying deviations from the baseline at the earliest possible instance is absolutely necessary to alleviate risk, development alternatives, and budget modifications to allow the acquisition to continue. Earned Value Management has the potential to identify and alleviate the risk if properly implemented. The key to the effective use of earned value is an adequate management control system that fosters the proper planning and integration of work on a project (Christensen and Gordon 1998). This study seeks to provide factual information concerning the applicability of

Earned Value Management in the software acquisition process.

II. Literature Review

This chapter is intended to give an overview of some of the problems that have been inherent in the software acquisition process. It is not sought to find a resolution for these problems, but to set the basis for why Earned Value Management has been developed and problems it attempts to overcome. The chapter will then cover the software acquisition life cycle, with a description of each of the phases. It will differentiate the stages of the life cycle with elements that are peculiar to each stage. The chapter will conclude with a comprehensive discussion of the Earned Value Management process. This discussion will center on the components of earned value and how they may be applied to the stages of the software acquisition process.

Software Requirements and Definition

Problems with Translation of Requirements. The translation from user needs into a viable concept involves the interaction of several groups. The primary groups are the operations and acquisition communities. Economic perspectives might hinder the operations community. The

user seeks to simplify processes, because this will increase productivity and lower operations costs. They desire easily understood and applied capabilities, which may be unreasonable expectations of the complex software behind the system (DeMarco, 1982). The initial requirements are often embryonic, as they evolve from the inception of the program through statement of work, proposal preparation and development, in order to take advantage of the latest technological breakthroughs (Marciniak and Reifer, 1990). Continuous management of new requirements from the user and derived requirements conceived by the developer is absolutely necessary because of their impact on cost estimation.

The acquisition community is often hindered by lack of practical experience with the systems they are procuring. They may be armed with training and book knowledge about the system, but they have never experienced the intricacies and peculiarities involved with operating the system – if they have ever been involved in operations at all. They could have trouble understanding the basis or reasoning behind detailed user requirements; thus they should spend extensive time reviewing and verifying the requirement to ensure completeness, correctness and relevance (Cooper and

Fisher, 1979). They have to work closely with the operations group, a resource adept in the situation experienced with the current system. Elaborate design and interfaces are useless if the users reject them, perceiving the system does not meet their needs (Cooper and Fisher, 1979).

Estimation of Software Projects Difficult. Estimation can be a particularly difficult task for the complex and revolutionary systems that are typical of the DOD. Many of these custom systems and applications do not have any standards to base an estimate from, especially when considering the software system may be for a developmental aircraft or space command and control system. Lack of estimating expertise, biases, inflated expectations, a poor understanding of the development, political considerations, and failure to estimate based on past performance are problems experienced in estimation (DeMarco 1982).

The DOD also hinders the estimation process. Vague or incomplete specifications limit the ability to interpret and properly apply the amount work to be accomplished to the cost estimation model. This leaves to the estimator's discretion the scope and size of the job. The specifications may fail to state directly what is needed,

but instead specify the user's solution to the problem. This restricts the creativity of the developer, disallowing a more cost and productivity efficient solution (Shamlin 1985). The estimate also may not be independent and objective, but subject to estimator project involvement, competitive business practice or program manager influence (DeMarco 1982). These factors will likely provide an inadequate estimation, setting the basis that may be impossible for the program manager to attain.

The conversion of the specifications into proper cost estimation determinants must also be done in a manner to properly size and fund the project. The value of the cost estimation model is only as good as the inputs and their representation of the work that must be accomplished. A standard used for cost estimation is Lines of Code (LOC). The difficulty in using LOC for software estimation is that the number needed is not well known until the coding is near completion, while the estimate must be made before the requirements analysis for budgeting and planning purposes.

There are other problems inherent in using LOC as a basis for estimate. There are no national or international standards for the application of LOC that encompasses all procedural languages. LOC may be counted using physical or

logical lines. LOC counts may include executable lines, data type definition, comments and even blank lines. Reusable code may be counted several times. Code reuse accounts for 20-30 percent of programming in procedural languages such as C, COBOL or FORTRAN (Jones 1991).

Software may be developed using spreadsheets, program generators or embedded commercial-off-the-shelf (COTS) programs, where the development of LOC is less significant. The type of language being utilized will have an impact on the LOC level, with the higher level languages providing LOC estimates that are incomparable with code-intensive lower level languages. Some applications employ the use of several different languages, such as Ada mixed with assembler language (Jones 1991).

Translation of Estimation into Effective Program Management Measures. This LOC estimate does not take into account several of the non-coding factors that have major implications on the cost and schedule of the acquisition. These are termed hard and soft data. The hard and soft data must be matched with the LOC normalized data to provide realistic estimates of the project.

Hard data includes the number of members to be assigned to the project. When determining this number, the

amount of time allocated to each of the project tasks, such as requirement definition and product design, must be distinguished from programming time. The schedule duration of project tasks is included, accounting for the overlap and concurrency of tasks being performed in parallel. The amount of documentation and test cases to be required is involved in the estimation. The number of bugs and defects expected are also budgeted. These hard data items, with little or no subjectivity, are more easily quantifiable than soft data items (Jones 1991).

Soft data is more difficult to measure and budget, because much of it is based on human opinion. The skill and experience of the team is a major consideration. The make-up of the team will likely range from recent college graduates to those with operational experience to seasoned business professionals. Constraints and schedule pressures may come from within the development team or from the user community, who needs the product *yesterday*. The stability of the project requirements has an impact, and it must be controlled by the program manager to prevent *creeping requirements* from steering the program off course. Other determinants include expertise and cooperation of the user,

tool and methodology adequacy, organizational structure and adequacy of office space (Jones 1991).

The program manager must adequately allocate the resources made available from the budgetary allocations and authorizations. Cost and schedule are constraints on the program manager in achieving the level of performance necessary to complete the project. A translation is made between the LOC or function points basis used for the cost estimation to a level of effort (LOE) parameter. This LOE is a resource allocation metric that will measure the amount of man-hours that have been expended in planning, programming and analysis by the development team. A major drawback of this performance measure is that is does not measure the amount of progress that has been made toward requirements analysis, program design, programming, test and integration.

Software Project Development

Software System Concept/Requirements Analysis Phase. The systems concept phase is the determination of the need and scope of the software system to be acquired. The types of systems may involve a software intensive (command and control, management information or radar interpretation),

software reliant (aircraft avionics or missile targeting) or embedded commercial-off-the-shelf (COTS) systems. In either case, it is absolutely necessary that the acquisition community have a clear and comprehensive understanding of the users' needs. A survey of over 8000 software projects found that lack of user input, incomplete requirements and changing requirements were the top reasons that projects were delivered late, over budget and with less functionality than desired (The Standish Group, 1994).

The foundation of the software project is based on four documents. These documents include the Concept of Operations (CONOPS), System Requirements Specifications, Software Requirements Specifications and the Project Plan (Turner 1997). The understanding of user need is heavily reliant on the validity and stability of these documents and their incorporation into the government-provided Statement of Objectives (SOO). The System Requirements Review (SRR) and System Design Review (SDR) are opportunities for the validation and clarification of the requirements. This understanding will facilitate the proper estimation and determination of the computer software configuration items (CSCIs) necessary for the software acquisition project (Murtagh 1992).

Planning Phase. The planning phase involves placing the proper personnel and material in a manner to facilitate performance while minimizing risk. Planning cannot be effectively accomplished until the requirements are stable and understood. Internal (e.g. operational) and external (e.g. Congressional) pressures, along with the amount of developmental work necessary, may affect the development of milestone schedules. To properly utilize resources, the developers should have a detailed Work Breakdown Structure (WBS) to place the resources against. A network schedule will also be developed to determine the critical path and allow resource balance. This will allow the allocation of risk and resources to meet schedule requirements while preventing the development of additional critical paths.

Software System Design/Coding Phase. Before the software system design phase can be undertaken, it is absolutely crucial that the software requirements analysis was done well (Murtagh 1992). Often the software community will undertake the design and coding before the requirements are stable and understood, which eventually leads to extensive rework resulting in cost and schedule impacts. Schedule pressures that drove the premature

design and coding ultimately lead to waste of valuable resources and delays.

The primary components of the design phase are the preliminary and detailed design reviews. The preliminary design breaks the CSCIs into computer software components (CSCs) and determines what requirements each will fulfill. The interfaces for each of the CSCs are identified and documented. All the requirements from the SOO and the resulting Statement of Work (SOW) are addressed, providing traceability of requirements (Murtagh 1992). This review is a combined effort of the developers, customers and users. Any changes to the software specifications after the PDR should be reserved for the next system upgrade (Turner 1997).

The detailed design identifies the resources that will be used to develop each CSC by breaking them down into computer software units (CSUs). According to DoD-STD-2167A, this involves the definition of the structure, interfaces, data flow and control flows of the CSCs and CSUs. Although not the current standard, the ideas are still valid. The design requirements are established and finalized. This review bridges the gap between the top-

level design and the coding. This design includes a description of the following (Turner 1997):

- software components (units or modules)
- interfaces between components
- data structures
- input/output screens
- timing and memory constraints
- performance measurements
- error handling

The efforts of the detailed design phase culminate in the Critical Design Review (CDR). Following the CDR, coding and unit test is conducted for each CSU.

System Implementation/Testing Phase. The software system implementation and testing phase is initiated with the reconstruction of the tested CSUs into CSCs. The aggregate CSCs are tested with the integration of each CSU. Testing is also conducted between dependent CSCs. The same testing is conducted for COTS products that are integrated into the software system.

During this testing, configuration verification and performance validation is accomplished. Not only do the software components have to work in concert, but they also have to provide the desired functionality. Verification ensures the CSCI performance meets the design specifications, while validation ensures that the software satisfies the intended use. The verification and

validation team should be independent of the authority of the development manager. The team must accomplish several tasks in exercising the software, including the following:

- traceability analysis
- requirements validation
- interface analysis
- software system test plan generation
- acceptance test plan generation
- algorithm analysis
- auditing
- control flow analysis
- database analysis
- simulation
- inspections/walk through

The ultimate purpose of testing is to exercise the code in order to expose errors (Turner 1997).

Operations and Maintenance Phase. The operations and maintenance phase should be a relatively stable period if the requirement analysis, design, testing and integration were thorough and successful. There are several other factors that must be considered, though. Dependent on the type of project, it might be too cost and schedule extensive to test all the bugs out of the software. There are often fixes that are required after fielding the system. Specification changes introduced after the PDR will need to be incorporated into system releases and upgrades. Operational requirement changes will necessitate coding modification. Schedule constraints may also drive

the need for pre-planned product improvement (P^3I) measures, providing the functionality that would have been available if adequate time had been given to fully design and test the system.

Earned Value Management

Overview. Earned Value Management (EVM) is a system that can help identify and prevent the shortcomings associated with managing by LOE tracking. EVM is a technique that, coupled with an effective cost estimation method, provides the program manager with valuable information about how a program is progressing at any given time. EVM uses the same work units used in the cost estimation; it applies a dollar and time value to each of the work units. No longer does the manager have to simply manage based on cost and scheduled manpower, which tells nothing of the actual progress that has been accomplished.

The earned value concept has existed within the government for decades in an inflexible and formalized manner. The earned value idea was initially mandated with the imposition of 35 Cost/Schedule Control Systems Criteria (C/SCSC). All firms wishing to participate in cost reimbursable or incentive contracts were required to adhere

to the criteria, which some considered to be an Utopian ideal that was difficult to emulate and employ on all contracts (Fleming and Koppelman 1998). Although C/SCSC provided useful information in predicting cost and schedule results, industry resisted C/SCSC because it contained too many perceived non-value added requirements.

Earned Value Management in its current form is a more cooperative program between the government and the industry. After years of imposing strict, mandated criteria on the contractors, the government encouraged feedback and incorporated it into the requirements of the program management scheme to be developed. The National Security Industry Association (NSIA) was chartered with assessing the utility of the earned value criteria and rewording the criteria to make it more palatable to the project management community (Fleming and Koppelman 1998). The current environment even allows tailoring to meet the needs of the contractor, especially since it a contractor-owned instead government-imposed system (evms.dcmdw.dla.mil 1998). The tailored Earned Value Management System (EVMS) must simply be certified and accepted by the government.

EVM in the Software Environment. The results of the cost estimation must put the work to be done in measurable

units that can be tracked using EVM. The government includes EVM as the cost and schedule tracking system in the Statement of Work and contracts for it accordingly. There are several different work unit groupings that could be employed: product, component, activity, defect, enhancement, phase, LOC or objects (Grady 1992). The work unit measurements may also be applied to individual work teams (Harvey 1995). The program manager should allow the contractor to determine the appropriate measures that will best fit the contractor's recording methods, since the actual monitoring and reporting is accomplished by the contractor. The status is reported at regularly scheduled status meetings, on demand or through access via Electronic Data Interchange (EDI).

Application of EVM. EVM is comprised of three components. Unlike previous methods of tracking, EVM monitors the number of work units (not dollars or man-hours) versus time. Budgeted Cost of Work Scheduled (BCWS) is the number of work units scheduled for completion at a particular time based on the results of the cost estimation. Actual Cost of Work Performed (ACWP) is the number of work units that have been completed at a particular juncture in a program. BCWP shows how many work

units have been completed in comparison with the amount estimated to be complete (BCWS) and the amount actually used (ACWP) to get to the present (Cruver 1997). Following is an example of EVM in practice:

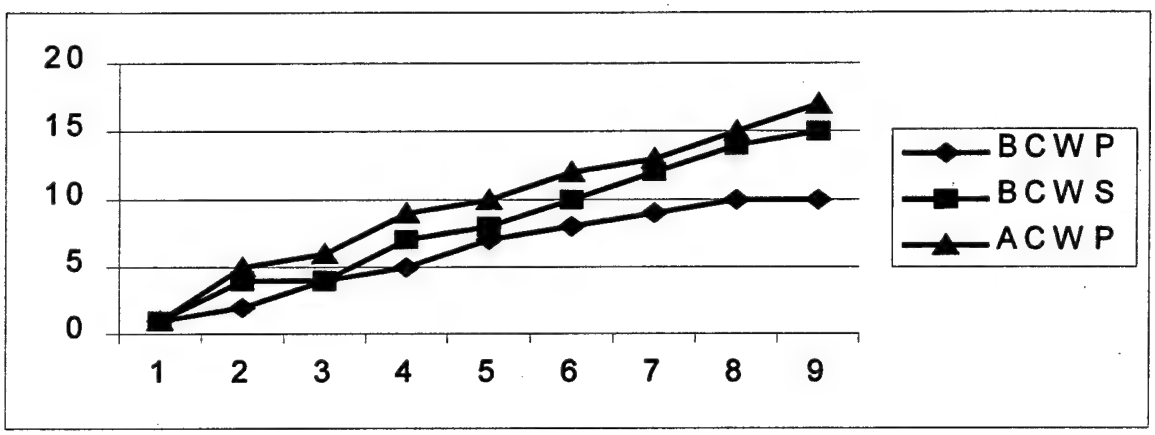

Figure 1. EVM in Application

At point number 9 in Figure 1, 15 work units were scheduled for completion. Only 10 work units had actually been completed at this point, but it took 17 of the estimation-based units to complete the work that had been done.

The cost and schedule variance can easily be determined from the preceding figure. The variance equations are as follows:

$$CV = BCWP - ACWP \quad (1)$$

$$SV = BCWP - BCWS \quad (2)$$

where CV is cost variance, BCWP is Budgeted Cost for Work Performed, ACWP is Actual Cost for Work Performed and BCWS is Budgeted Cost for Work Scheduled.

The cost variance is determined by subtracting ACWP from BCWP. This determines the difference in the number of work units that were completed and the actual number of work units expended for the work done. The program manager got 10 work units for the price of 17 work units, meaning there is a cost variance of -7 work units.

The schedule variance is determined by subtracting the BCWS from BCWP. The estimation determined 15 work units should be completed at this point, but only 10 were. The program manager now has a schedule variance of -5 work units. The program manager can easily discern at this point that actual work completed is behind schedule and costing much more than had been budgeted.

Estimate at Completion (EAC) is the total amount of work units from the estimation model for accomplishing the software acquisition project. This number is the baseline, but will likely be adjusted based on actual results.

There are several methods of determining an EAC. The Budget at Completion (BAC) is the budget based on the original estimation for the contract performance. The Cost Performance Index (CPI), which is the ratio of budgeted cost for work performed to the actual cost incurred, is determined by the following:

$$CPI = \frac{BCWP}{ACWP} \qquad (3)$$

The first method of determining EAC assumes that the cost performance experienced to date will remain the same for the remainder of the contract.

$$\text{Method 1: } EAC = \frac{BAC}{CPI} \qquad (4)$$

The next method of determining EAC assumes that past performance is not indicative of future performance on the contract. This method does allow for the revision of the planned cost based on the historical data from completed work packages.

$$\text{Method 2: } EAC = \frac{OCW}{CPI} + RCWNYB \qquad (5)$$

where OCW is Open and Completed Work and ARCWNYB is Revised Cost of Work Not Yet Begun.

Another method of determining EAC assumes that the remaining work is independent of work completed to date. This may be unrealistic as work packages may influence performance of subsequent work packages—especially on the critical path. This method is very risky if revision of the estimates is not allowed.

$$\text{Method 3: } EAC = ACWP + RWPC \qquad (6)$$

where RWPC is Remaining Work at Planned Cost.

There are several other methods available for the determination of EAC, with their value differing based on the dollar value, risk, cost accounting system and estimation accuracy of the project (Kerzner 1998:815-6).

As soon EAC begins to rise above baseline, the program manager should find ways to cut costs or secure additional funding. At this time, the program manager should confer with the contractor to determine the Latest Revised Estimate (LRE), which is the best guess concerning what it will cost in work units to complete the program (Cruver 1997). This is a crucial decision point to determine whether or not to continue the program, as errors and poor judgment may lead to escalation and "throwing good money after bad" (Kiel 1995).

III. Methodology

This chapter describes the methodology used in acquiring and analyzing the data used in the conduct of the study. It will describe the data collection instrument development, the administration of the data collection instrument, the subjects and the analysis to be performed on the gathered information.

Justification of Approach

A structured questionnaire is used to collect the data for analysis due to the fact that data concerning user satisfaction with EVM is not currently available. The questionnaire, with room for comments on each question, will allow the participants to openly and candidly comment on each of the statements anonymously. A questionnaire will also allow the participants to answer at their discretion within time limitations necessary for adequate analysis, as many acquisition officials cannot set aside a specific for these purposes. A preferred approach would be to conduct personal interviews to record subjects' tone and gestures, but this would be at the expense of a great deal of time, coordination and respondent anonymity.

Instrument Development

The design of this study is based on a structured questionnaire consisting of 25 statements in regard to perceptions of several categories (insight, usability, etc.) and their relation to the Earned Value Management process. Another question regards performance metrics utilized for tracking cost, schedule and performance. The entire questionnaire is included as Appendix E.

The questionnaire is limited to 25 statements and one question to keep it from requiring too much of the respondent's time. It is hoped that this will keep the respondent's attention, allow for honest and thoughtful answers and improve the response rate. The response pattern is based on the Likert Scale, with responses to each statement limited to the choice of one of five possible agreement levels (Cooper 1979). There will be an area following each question to allow for comments, which could provide useful insight into the response. The response scale range follows:

5 - Strongly Agree
4 - Agree
3 - Neither Agree or Disagree
2 - Disagree
1 - Strongly Disagree

Four broad categories set the basis for the analysis of user satisfaction and utility in the administration of the Earned Value Management System. The categories (with their corresponding appendix) include the following:

- Insight/Representation (A)
- Usability (B)
- Comparison with previous/other current systems (C)
- Life cycle applicability (D)

Insight and Representation. The insight and representation statements are used to determine the satisfaction of acquisition community members with the ability of Earned Value Management to provide precise, meaningful information. Insight pertains to the availability of programmatic information in the proper amount and depth necessary to understand program status and make informed decisions. Representation deals with work depiction accuracy and comprehension of the portrayal of the contractor's work expenditures and accomplishments to the government representative.

There are ten statements regarding insight and representation. The statements deal with precision, forecasting utilization and translation from cost estimation measures into identifiable, representative work units. The statements deal with the ability of the government to use these work units to understand and budget

cost and schedule progression and identify variation using Earned Value Management. The insight questions can be referenced in Appendix A.

Usability. Usability pertains to the complexity involved in the utilization of the Earned Value Management System for software project management. The usability statements seek to determine both the ease of use of the system for cost, schedule and performance tracking as well as the burden shared by the government and contractor in using the Earned Value Management System.

There are six statements regarding the usability of the Earned Value Management System. The statements deal with the relative ease of program management using earned value, understanding of the earned value system and government-contractor obligations to the system. The questionnaire also contains a statement regarding the effectiveness of earned value for hardware systems acquisition for comparison with software systems. The usability questions can be referenced in Appendix B.

Comparison with Previous/Other Current Systems. This category is being used to determine the preference for Earned Value Management or another management system for software program management. This information is important

to understand government and contractor preference for either system based on capability and performance. Preference for a previous or other current system may be indicative of a natural resistance to the Earned Value Management philosophy.

There are three statements with regard to comparison with previous/other current systems. These seek to determine the adequacy of previous systems, whether better program management systems exist and whether the subject perceives Earned Value Management to be just a current buzzword. These statements will help determine whether Earned Value Management lives up to its billing in providing cost and schedule management capability not otherwise available. The comparability questions can be referenced in Appendix C.

Life Cycle Applicability. Life cycle applicability statements pertain to the application of the Earned Value Management System across all stages of the software development life cycle. This information will help in understanding whether the acquisition community feels this program management system is a stand-alone tool, or one of multiple tools program managers need to have at their disposal. This will also be useful in determining the

appropriateness of earned value for project management, as complexities and information loss are risks associated in the transition between different management systems at successive stages of the life cycle.

There are six statements regarding life cycle process applicability. These statements determine whether the system concept/requirements analysis, planning, design/coding, implementation/testing and operation/maintenance phases are enhanced by the use of Earned Value Management as the program management tool. The life cycle applicability questions can be referenced in Appendix D.

Instrument Administration

The questionnaire was distributed through mailings and electronic mail to the various segments of the government acquisition community. It was also distributed to the contractor community through meetings of the Dayton chapter of the Institute of Electrical and Electronics Engineers (IEEE) and Association for Computing Machinery (ACM). The questionnaires were taken at the respondent's leisure within deadlines necessary for adequate analysis. The questionnaires were accompanied with a self-addressed,

stamped envelope (SASE) for collection. The SASE is included for respondent convenience and to encourage enhanced return rates.

Data Analysis

The responses were distinguished between government and contractor subjects. The responses are distinguished by identification as a government or non-government employee at the end of the questionnaire. The responses have been analyzed to determine the mean level assessment of Earned Value Management for each of the identified categories. This will determine the overall level of satisfaction from both the government and contractor perspective of the success of the earned value scheme.

The categorized response levels were determined by calculating the mean score for the questions making up the category. For instance, the response level for the category of insight and representation was determined by the following:

$$\text{Mean}_I = \frac{\sum_{1\ldots n} \frac{(A + B + G + P + Q + R + S + V + X + Y)}{10}}{n} \quad (7)$$

A, B, etc. = Corresponding statement number in alphabet
n = Number of respondents

The corresponding values for the response to the statements will be as follows:

5 - Strongly Agree
4 - Agree
3 - Neither Agree or Disagree
2 - Disagree
1 - Strongly Disagree

The categorized responses will then be analyzed between the government and contractor to determine differences in the perceptions of the utility of Earned Value Management. This analysis of means will help determine whether or not the government and contractor realize the same benefit or detriment from the use of the earned value scheme.

Conclusion

This section describes the formulation, administration and analysis of the study. The analysis will provide insight into the perceived applicability and utility of Earned Value Management according to those using it in the acquisition community. This seeks to provide evidence as to the usefulness or confusion resulting from the broad application of the Earned Value Management System.

IV. Data Description and Analysis

Overview

The structured questionnaire gauged the level of government and contractor responses to categories including insight, usability, comparability, and life cycle applicability of the earned value philosophy. The response levels are presented from the government, contractor and aggregate perspectives. Only the individual statements that deviated from the category mean are indicated and discussed. Statements that deviated substantially from the mean represent areas of concern that potentially need to be addressed by project managers. The substance of the statements that are not individually addressed is captured in the category discussion.

Insight

The respondents indicated that EVM allowed adequate insight into project management. The government respondents indicated a higher level of insight using EVM than the contractors. The questions regarding insight (Appendix A) had an overall mean response level of 3.425, a government mean of 3.533 and a contractor mean of 3.317. This indicates that government employees perceive a greater

level of project management insight from the application of EVM than contractors, who use EVM to report progress.

Table 1. Means for Insight Category and Questions

	Combined	Government	Contractor
Overall Insight	3.425	3.533	3.317
Adequacy of EVM for tracking cost and schedule	4.083	4.000	4.167
Ability of EVM to forecast cost and schedule variance	3.833	4.000	3.667
Translation from cost estimation to EVM tracking parameters	2.833	2.667	3.000
Adequacy of current software metrics for EVM tracking	3.083	3.833	2.333

The questions that deviated substantially from the mean will now be addressed. Respondents indicated a high level of agreement concerning the adequacy of earned value information in tracking cost and schedule performance. The mean for this question was 4.083, with the government and contractor means being 4.000 and 4.167, respectively. There were also high response levels for the ability EVM to forecast cost and schedule variance, with the aggregate mean being 3.833, government 4.000 and contractor 3.667.

Respondents were less enthusiastic about the adequacy of tools for translating cost estimation parameters into EVM data. Insight can be inhibited by the poor conversion from cost estimation into program management tracking data. The mean concerning cost estimation translation was 2.833, with a government mean of 2.667 and a contractor mean of 3.000. Respondents also indicated that current software metrics were inadequate for tracking progress using EVM. The aggregate, government and contractors means were 3.083, 3.833 and 2.333, respectively. The high variability between government and contractor means indicates a disparity in the usefulness of current metrics for tracking progress.

Usability

Respondents indicated EVM has a high degree of usability in project management. Both the government and contractor respondents were comfortable with the usability of EVM for effective project management. The questions regarding usability (Appendix B) had an aggregate response level of 3.889, similarly high government (4.083) and contractor (3.694) means. This indicates a mutual understanding of the use and application of EVM for project management.

Some areas stood out from the overall category mean. Respondents gave strong indications that the implementation of EVM has not been time or cost prohibitive. This indicates that the training necessary to effectively apply EVM and the conversion from previous program management parameters into EVM structures did not consume a great deal of personnel or financial resources. The aggregate mean for this question was 4.167, with corresponding government and contractor means of 4.333 and 4.000.

Table 2. Means for Usability Category and Questions

	Combined	Government	Contractor
Overall Usability	3.889	4.083	3.694
Ease of implementation of EVM system	4.167	4.333	4.000
Understanding of EVM system and tracking information	4.167	4.500	3.833

Respondents also felt comfortable with their understanding of how the EVM system is applied and interpreted. The aggregate mean was 4.167, the government mean was 4.500 and the contractor mean was 3.833. Again there is a disparity between the government and contractor scores, with the contractor score being substantially

lower. While the contractor scores are still high, this is a potential concern and training may help bridge the gap.

Comparison with Previous/Other Current Systems

The lowest scores of the questionnaire dealt with the comparability of EVM with previous systems of project management. An important consideration for choosing to introduce a new project management system is that is provides additional capabilities and easier administration than the system being replaced. The aggregate response level for the comparability questions (Appendix C) equaled 3.306, with the government mean equaling 3.611 and the contractors' exactly 3.000. This is an indication that the contractors may feel EVM is simply the incorporation of the previous systems under a new name.

Table 3. Means for Comparability Category and Questions

	Combined	Government	Contractor
Overall Comparability	3.306	3.611	3.000
Previous cost and schedule tracking difficulty	3.500	3.667	3.333
Preference of EVM over other management systems	3.083	3.500	2.667

Respondents indicated that previous systems had difficulties affecting their adequacy to track cost and schedule performance. Granted that EVM parameters are a subset of the extensive 35 C/SCSC, but the response levels show an enhanced capability of EVM to monitor cost and schedule performance over C/SCSC and other systems. The mean response level for the entire sample was 3.500, with corresponding means for the government (3.667) and contractor (3.333) groupings.

The results were inconclusive pertaining to the preference for EVM over other program management systems. The combined mean was 3.083, with a government mean of 3.500 and a contractor mean of 2.667. The disparity between the means of the government and contractor community needs to be addressed. The government must discern whether the contractors are using different systems for internal program management or whether refinements may need to be made to the EVM system.

Life Cycle Applicability

Respondents generally agreed that EVM has potential for application across several stages of the project management life cycle. The questions concerning life cycle

applicability category (Appendix D) had an aggregate response level of 3.514, with the respective government and contractor means of 3.639 and 3.389. While the scores were indicative of broad application across the several different stages of the life cycle, there was an indication that EVM is more useful for some stages of the software project management life cycle than others.

Table 4. Means for Life Cycle Category and Questions

	Combined	Government	Contractor
Overall Life Cycle Applicability	3.514	3.639	3.389
EVM more useful for some stages of project life cycle	3.000	3.000	3.000
Management of systems concept/ requirements analysis phase	4.000	4.000	4.000
Management of the software system design/coding phase	4.000	4.000	4.000
Management of the operations and maintenance phase	3.000	3.500	2.500

The management of the software system design/coding phase was found to receive the highest scores for the application of EVM. This is important information because this has been a difficult area for acquisition officials to monitor and control. It is also beneficial because it allows the contractors to more accurately portray progress

on software projects. The response level was 4.000 for the combined, government and contractor means.

Both government and contractor respondents indicated that EVM is more useful for some phases of system acquisition than others. The response level again was 4.000 for the combined, government and contractor means. The areas considered to be less conducive to earned value management will now be explored.

The systems concept/requirements analysis phase was one of the areas where EVM was found to be less useful for project management. This may be due to the exploratory nature and difficulty in quantifying the work of the phase. The mean was 3.000 for the combined, government and contractor means.

The operations and maintenance phase was another area found less conducive to the application of the EVMS. This is likely due to the fluctuation in the requirements that may occur in the duration of the operations phase. There are surges and changes in operational concepts that may be difficult to foresee or quantify at the onset of a contract administration. The maintenance phase will fluctuate along with the changes in operations, and this could be difficult to budget and manage with the EVMS. The combined mean was

3.000, with a government mean of 3.500 and contractor mean of 2.500. The difference in means between the government and contractor may be explained by their vantage points as consumer and provider.

V. Conclusions and Recommendations

Overview

This chapter identifies the findings, limitations and recommendations for follow-on research for this study. It will discuss the findings pertaining to insight, usability, comparability and life cycle applicability in accordance with the Earned Value Management System. The limitations of the study and the structured questionnaire will be addressed. Possibilities for follow-on research will also be presented and offered.

Findings

Earned Value Management allows an adequate level of insight into project management for both the government and contractor communities. Government employees perceive a slightly higher level of insight than their contractor counterparts. This is explained by the fact that the Government uses EVM as a project status and control tool, while the contractors use EVM as a project-reporting tool. Greater insight into software projects will help acquisition officials prevent these projects from becoming cost and schedule prohibitive.

Earned Value Management is very helpful in the tracking of cost and schedule in project management. EVM

also enables acquisition officials to identify potential cost and schedule variances earlier to either prevent them or implement contingency plans to minimize their effect. More attention needs to be placed on the transformation from the cost estimation metrics into earned value measures to prevent information loss. Attention also needs to be directed to the metrics, which were indicated to be inadequate for accurate tracking using EVM.

Government and contractor employees are satisfied with the usability and implementation of EVM into project management. This is an important consideration, since the rejection by either party would doom the new project management system to failure. Both parties must have a good understanding of how to administer EVM and interpret its information in order for the new philosophy to be effective and successful.

The implementation of EVM was not indicated to be resource prohibitive. Neither the contractor nor the government indicated that too many resources were expended with the integration of EVM into their programs. Personnel's training has been sufficient, and the conversion from previous program management into EVM parameters did not pose extensive problems.

Program participants are comfortable with their understanding of how the EVM system is applied and interpreted. The disparity between the government and contractor scores is a concern. Attention needs to be given to address contractor concerns or training deficiencies related to Earned Value Management philosophy.

A preference for EVM over previous program management schemes is inconclusive. Government employees indicate a preference for EVM over C/SCSC and other program management schemes, but the contractors have no preference. If the contractor community does not discern a difference and an enhanced capability, other than its ability to track cost and schedule progress, EVM runs the risk of being another comprehensive system that burdens the contractors.

EVM is applicable across several stages of the project management life cycle. Although EVM is applicable across several different stages, EVM is more useful for some stages of the software project management life cycle than others. This indicates that EVM is simply one of several management schemes needed for management of the project throughout the entire life cycle.

Management of the software system design/coding phase is well suited for the application of EVM. This has been

one of the most difficult areas for acquisition officials to monitor and control. This will allow more accurate portrayal of progress during this phase, but only if an accurate understanding of the coding necessary is represented in the EVM tracking parameters.

The systems concept/requirements analysis and the operations/maintenance phases are areas where EVM is less useful for project management. Attention must be directed to overcome this discrepancy. Several approaches are available. EVM can be modified to be better applicable to these phases. Other program management schemes can be employed for these phases if their nature is not conducive to EVM tracking. If possible, training can be accomplished to show how EVM is usable in these phases.

Research Recommendations

The following recommendations can be made for follow-on research from this study:

a. A study focusing on the different levels of management (senior, middle and lower) and their perceptions of the applicability of EVM would determine if gaps exist between government and/or contractor management echelons.

b. A detailed investigation of different types of acquisition projects (hardware development, software development, COTS integration, operations and maintenance) would determine distinctions in the applicability of EVM.

c. A case study showing a comparison of the success of EVM and C/SCSC in acquiring similar systems would provide a comparison of the their ability in meeting cost, schedule and performance requirements.

Conclusion

Earned Value Management is a program management tool that is easily integrated and applied by the government acquisition community. EVM gives government officials much greater insight into the cost and schedule aspects of an acquisition by tracking these parameters against the amount of work scheduled to be completed at a given time. EVM allows better forecasting of cost and schedule variances and planning for their resolution. The applicability of EVM is more useful for some phases of the software acquisition life cycle than others, and program management officials must find alternatives or modify the EVMS to account for peculiarities of the different phases.

Appendix A: Insight Questions

1) EVM provides adequate insight into cost and schedule performance.

2) EVM allows adequate forecasting of cost and schedule variances.

3) EVM better allows my project to be completed within cost and schedule.

4) Adequate tools exist to translate cost estimation parameters to EVM.

5) Project management information gets lost in the transition from cost estimation to EVM.

6) Current software metrics are adequate for tracking progress using EVM.

7) Software defects and modifications can be tracked using EVM.

8) EVM is not precise enough to give the level of detail necessary for program management.

9) EVM allows adequate representation of contractor performance.

10) The program management approach used by the contractor captures the data needed for EVM reporting to the government.

Appendix B: Usability Questions

1) The use of EVM makes program management easier.

2) The use of EVM is not worth its time and dollar expense.

3) Software projects can be effectively managed using EVM.

4) Hardware projects can be effectively managed using EVM.

5) I have a good understanding of how the EVM system actually works.

6) EVM shifts the government cost and schedule tracking burden to the contractor.

Appendix C: Comparability Questions

1) Previous program management systems were adequate for tracking cost and schedule performance.

2) The term "Earned Value Management" is a buzzword for the same old system.

3) Better program management systems exist that EVM.

Appendix D: Life Cycle Applicability Questions

1) Management of the system concept/requirements analysis phase is enhanced using EVM.

2) Management of the planning phase is enhanced using EVM.

3) Management of the software system design/coding phase is enhanced using EVM.

4) Management of the system implementation/testing phase is enhanced using EVM.

5) Management of the operations and maintenance phase is enhanced using EVM.

6) EVM is more useful for some phases of the system acquisition than others.

Appendix E: Structured Questionnaire

Please use the following scale to respond to the statements:

Strongly disagree (1)	Disagree (2)	Neither agree or disagree (3)	Agree (4)	Strongly agree (5)

1) Earned Value Management provides adequate insight into cost and schedule performance. 1 2 3 4 5

Comments:

2) Earned Value Management allows adequate forecasting of cost and schedule variances. 1 2 3 4 5

Comments:

3) The use of Earned Value Management makes program management easier. 1 2 3 4 5

Comments:

4) The use of Earned Value Management is not worth its time and dollar expense. 1 2 3 4 5

Comments:

5) Previous program management systems were adequate for tracking cost and schedule performance. 1 2 3 4 5

Comments (Which systems?):

6) The term "Earned Value Management" is a buzzword for the same old system. 1 2 3 4 5

Comments:

7) Earned Value Management better allows my project to be completed within cost and schedule. 1 2 3 4 5

Comments:

8) Better program management systems exist than Earned Value Management. 1 2 3 4 5

Comments:

9) Management of the system concept/requirements analysis phase is enhanced using Earned Value Management. 1 2 3 4 5

Comments:

10) Management of the planning phase is enhanced using Earned Value Management. 1 2 3 4 5

Comments:

11) Management of the system design/coding phase is enhanced using Earned Value Management. 1 2 3 4 5

Comments:

12) Management of the system implementation/testing phase is enhanced using Earned Value Management. 1 2 3 4 5

Comments:

13) Management of the operations and maintenance phase is enhanced using Earned Value Management. 1 2 3 4 5

Comments:

14) Software projects can be effectively managed using Earned Value Management. 1 2 3 4 5

Comments:

15) Hardware projects can be effectively managed using Earned Value Management. 1 2 3 4 5

Comments:

16) Adequate tools exist to translate cost estimation parameters to Earned Value Management. 1 2 3 4 5

Comments (Which tools?):

17) Project management information gets lost in the transition from cost estimation to Earned Value Management. 1 2 3 4 5

Comments:

18) Current software metrics are adequate for tracking progress using Earned Value Management. 1 2 3 4 5

Comments (Which metrics?):

19) Software defects and modifications can be tracked using Earned Value Management. 1 2 3 4 5

Comments:

20) Earned Value Management is more useful for some phases of systems acquisition than others. 1 2 3 4 5

Comments (Which and why?):

21) I have a good understanding of how the Earned Value Management system actually works. 1 2 3 4 5

Comments:

22) Earned Value Management is not precise enough to give the level of detail necessary for program management. 1 2 3 4 5

Comments:

23) Earned Value Management shifts the government cost and schedule tracking burden to the contractor. 1 2 3 4 5

Comments:

24) Earned Value Management allows adequate representation of contractor performance. 1 2 3 4 5

Comments:

25) The program management approach used by the contractor captures the data needed for Earned Value Management reporting to the government. 1 2 3 4 5

Comments:

26) What metrics does your program office use to assess the value a contractor earns within a given reporting period? Please list and explain.

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Vita

Captain Louis D. Bryan was born on 21 June 1969 in Knoxville, Tennessee. He graduated from Sevier County High School in Sevierville, Tennessee in June 1987. He entered active duty by enlisting in the U.S. Air Force in August 1987. He received an appointment from active duty to the U.S. Air Force Academy in Colorado Springs, Colorado where he graduated with a Regular Commission and Bachelor of Science degree in Space Operations in June 1994.

His first assignment as an officer was at Onizuka AS, CA as a space operations flight commander in August 1994. He was assigned to Operating Division-4/DH, Secretary of the Air Force Special Projects. While stationed at Onizuka, he attended Undergraduate Space Training and earned a Joint Service Achievement Medal and a Joint Service Commendation Medal. In May 1998, he entered the Graduate Contracting Management program, School of Logistics and Acquisition Management, Air Force Institute of Technology. Upon graduation, he will be assigned to the National Reconnaissance Office.

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13. ABSTRACT (*Maximum 200 Words*)

The objective of this study was to determine the usefulness of Earned Value Management as a program management tool for the Department of Defense acquisition community. In making this determination, the study sought to uncover information about Earned Value Management from the contractor's perspective as well as the government administrator's perspective. It also sought to determine the usefulness of Earned Value Management during the different phases of the software acquisition process. The study utilized a structured questionnaire to acquire the data necessary for analysis. This data was analyzed to compare perceptions of the government and contractor communities in regard to the use of Earned Value Management as a program management tool. It also compared perceptions in regard to using Earned Value Management during different stages of the software program life cycle.

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